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(54) Solenoid construction and method for making the same.

(57) A proportional solenoid has a fixed pole piece (39) and a movable armature (45), both fitted into the bore (52) of a guide tube (36) that provides the required concentricity between the fixed and movable pole pieces (39) and (45). One of the pole pieces has a cylindrical recess (56) and the other pole piece has a reduced diameter cylindrical nose (62) that is complementary to cylindrical recess (56). A radially inwardly facing frusto-conical surface (95) is formed in cylindrical nose (62) to be disposed within recess (56) of the other pole piece and provide a frusto-conical pole piece section producing a linear force-stroke curve.

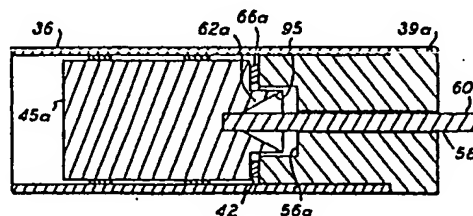


FIG. 5

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10 **TITLE**

SOLENOID CONSTRUCTION AND METHOD FOR MAKING THE SAME
BACKGROUND

Field of the Invention

This invention relates to solenoids and methods
for making the same and particularly proportional type
15 solenoids.

Description of the Prior Art

General purpose solenoids provide a force-stroke
curve whereby the force at a closed stroke gap is higher
than the force developed at the initial starting stroke
20 gap. These solenoids are sometimes referred to as
"on-off" solenoids and are energized ("on") to a fully
operated position or are de-energized ("off") to a fully
neutral position. In this type of solenoid, in order to
25 activate the armature to close the stroke gap, the
solenoid must only provide enough force to overcome the
load including any frictional or side-loading magnetic
forces perpendicular to the axis of motion.

Proportional solenoids have long been known in
the art to provide a force vs. stroke curve that allows
30 the output force of the solenoid to be proportional to the
electrical current applied to the coil. This proportion-
ality of the output force permits such a solenoid to
either fully or partially operate a load by selectively
35 applying either the full or a partial electrical current
to the solenoid coil and thereby may selectively position
the armature along the linear distance of the gap.

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In order to operate this type of solenoid accurately, the forces in the solenoid must be accurately controlled. Since the frictional and side-loading forces vary depending upon a number of factors that cannot be accurately controlled, including tolerances in manufacturing and the equipment being operated by the solenoid, desirably their effects should be minimized in the design of the solenoid.

The prior art history of proportional solenoids and problems of such solenoids are described in U.S. Patent No. 3,900,822, Column 1 (Hardwick).

The prior art proportional solenoid provided multiple complex bearing surfaces including a bearing between the armature rod and the stationary pole piece. For example, see the complex bearing and structural support for the armature in each of the prior art patents, German Patent No. 1,270,178 and U.S. Patents Nos. 3,870,931 and 3,970,981, in order to provide the necessary structure for a proportional solenoid and to provide concentricity of the armature. Such constructions required very fine manufacturing tolerances, and it was difficult assembly such solenoids.

In order to overcome the concentricity problems of the above prior art patents and provide a concentricity tube for maintaining concentricity of both the armature and fixed pole piece, a multiple section armature tube as shown in FIG. 1 of the drawings was invented. This multiple section tube 10 included a magnetic section 12 made of ferromagnetic material having an external frusto-conical surface 14. The next section of the tube is a non-magnetic brass ring 16 brazed or otherwise permanently fixed at the surface 14 to section 12 and is brazed or permanently fixed along an opposite frusto-conical surface 18 to a third section 20 made of ferromagnetic material. Thus, the non-magnetic brass ring middle section 16 provides the essential non-magnetic radial transverse frusto-conical gap, which gap is linearly coextensive with the stroke gap of the armature. The tube 10 is press fitted or otherwise permanently fixed to a stationary or fixed magnetic pole piece 22 made of

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ferromagnetic material. The composite armature tube 10 and stationary pole piece 22 are received and mounted in a solenoid coil (not shown).

A movable armature 24 made of ferromagnetic material is provided with a pair of spaced non-magnetic bearing surfaces 26 made by bronze bushings, for example. There is a non-magnetic shim 28 surrounding a push rod 30 permanently mounted on armature 24 and slidable in a center hole 32 of the stationary pole piece 22.

The construction of the three-section tube shown in FIG. 1 is similar to the construction shown in U.S. Patent No. 3,970,981 except that all three sections are brazed or otherwise fixed together to form one continuous multiple section, multiple metal armature tube.

SUMMARY OF THE INVENTION

The present invention includes a hollow solenoid armature tube adapted to be received in a solenoid coil, a stationary pole piece member fixed in one end of the tube, an armature member adapted for axial sliding movement in the tube, one of the members having an axially extending recess therein and the other of the members having a reduced in cross section end portion adapted to be received in and complementary to said recess. The member having the reduced in cross section end portion also has a radially internally facing frusto-conical surface formed within the recess, the tube thereby providing concentricity of the two members, and the tube having a non-magnetic section extending coaxially with the gap made by the stroke of the armature.

The present invention minimizes the concentricity problems with proportional type solenoids with a less complicated structure than prior art solenoids. This is done by containing both the stationary pole piece and the movable armature within the same cylindrical surface of a single metal armature guide tube.

The present invention pertains to proportional type solenoids. It is an object of this invention to provide an improved solenoid construction overcoming the problems of the prior art as described above.

It is an important object of this invention to
1 reduce the effects of magnetic side loading with simpler
structure than the prior art. This is done by controlling
the concentricity between a reduced diameter cylindrical
nose of the movable armature and the mating cylindrical
5 recess in a stationary pole piece. Concentricity is
maintained because both the movable armature and the
stationary pole piece are confined by the bore of a
one-piece metal guide tube.

It is further an object of this invention to
10 minimize magnetic side loading by providing a non-magnetic
space between most of the linear dimensions of the arma-
ture and the adjacent magnetic members, which can be
provided by at least several alternatives such as a
uniform non-magnetic bearing surface or simply making the
15 entire guide tube non-magnetic.

DRAWINGS

Figure 1 is a cross-sectional view of a prior
art solenoid tube and pole pieces;

Figure 2 is a cross-sectional view of one
20 embodiment of the present invention with a solenoid coil
and housing added;

Figure 3 is a cross-sectional view of a portion
of a second embodiment of the present invention;

Figure 4 is a graph showing the force-stroke
25 performance of the solenoid provided by the present
invention; and

Figures 5-8 are fragmentary, cross-sectional
views of alternative preferred embodiments of the present
invention.

30 DETAILED DESCRIPTION

The preferred embodiment of the invention
illustrated in FIG. 2 is a general purpose proportional
solenoid. The construction of the present invention is
readily adaptable to proportional solenoids requiring a
35 pressure tight bore such as those solenoids used in
hydraulic applications. Also, this invention is readily
adaptable to push-pull solenoids. The illustrated
embodiment includes an outer housing 31 made of ferro-
magnetic material. An end washer 32 and an end washer 33

made of ferromagnetic material are press fitted into the
1 housing 31. The housing 31 and end washers 32 and 33
encase an electrical winding or coil 34 that is wound on a
coil form (bobbin) 35.

A concentricity guide tube or hollow solenoid
5 armature tube 36 is preferably a one-piece metal tube made
of magnetic stainless steel material, defining a cylindrical
armature chamber 29 adapted to receive an armature
45 made of ferromagnetic material. The armature 45 is
adapted to slide axially in the armature chamber 29. The
10 armature tube 36 has a cylindrical non-magnetic middle
section 37 (described more in detail hereinafter).

In the embodiments of FIGS. 2-3 and 5-8, the
armature tube 36 is preferably made of semiaustenitic
steel (as described more in U.S. Patent No. 3,633,139),
15 such as that known as 17-7P.H. (precipitation hardening).
stainless steel. The non-magnetic (austenitic) section 37
provides hindrance to that portion of the magnetic field
trying to pass through the non-magnetic section 37 of the
armature tube 36, thereby providing a gap which is reduced
20 in magnetic force described more in detail hereinafter.
The remainder of the armature tube 36 on both sides of the
non-magnetic section 37 is magnetic (martensitic) in order
to minimize hindrance of the magnetic field passing
radially therethrough. Or, the armature tube 36 may be
25 entirely non-magnetic, when the armature tube wall
thickness is thin enough to keep the magnetic losses
sufficiently small to allow the solenoid to operate with
the desired efficiency.

Although from a manufacturing point of view it
30 would be more expensive and therefore less desirable, it
would be possible within the concept of this invention to
provide a welded or brazed together multiple section tube
having at least one non-magnetic section extending axially
along the desired gap, which is reduced in magnetic force,
35 in lieu of the one-piece tube 36, and still fulfill the
concept and functions of this invention.

There is a stationary pole piece 39 fixed in one
end of the armature tube 36 thereby defining one end of
the armature chamber 29. In the embodiment of FIG. 2.

stationary pole piece 39 has a radially externally facing
1 frusto-conical section 41 having a radially externally
facing frusto-conical surface 54 that is annular and
concentric to the center axis of the tube and that
surrounds an axial cylindrical concentric recess 56 (that
5 is also concentric to the tube axis) of the stationary
pole piece 39. Stationary pole piece 39 has a center bore
58 adapted to receive a non-magnetic push rod 60 per-
manently mounted on the armature 45. Bore 58 and push rod
60 are not necessary if the solenoid is designed for
10 pulling, rather than pushing. The stationary pole piece
39 is made of ferromagnetic material and has a linear
section with a reduced outside diameter 50 which is press
fitted into a bore 52 of the armature tube 36.

Thus, both the stationary pole piece 39 and the
15 movable armature 45 are maintained in concentricity by the
armature tube 36. The armature 45 is shown in FIG. 2 in
solid line in its energized position and is shown in FIG.
2 in broken line at 45A in its de-energized or "neutral"
position.

20 The non-magnetic section 37 of the armature tube
36 surrounds an air gap 38. The armature 45 has a reduced
in cross section axial cylindrical concentric end portion
or nose 62 surrounded by a shoulder 42. The reduced in
cross section portion 62 is received in and complementary
25 to the cylindrical recess 56 of the stationary pole piece
39. The shoulder 42 of movable armature 45 (as illus-
trated in the retracted position at 42A and as shown in
broken line on the armature in the retracted broken line
position 45A) defines the air gap 38 which extends axially
30 to the radially externally facing frusto-conical section
41 of the stationary pole piece 39.

The non-magnetic section 37 and air gap 38 in
the FIG. 2 illustrated embodiment each extend coaxially
from an internal radial end surface 40 of armature 45
35 represented by the line B to the line D (of FIG. 2), which
is the shoulder 42A when the armature 45 is in its
de-energized broken line position. In this embodiment,
the non-magnetic section 37 and air gap 38 exceed the full
stroke of the armature illustrated in FIG. 2. which full

stroke is between the lines B and E and includes a
1 "working stroke" between the lines B to C of FIG. 2 and an
"overtravel" stroke between the lines C and E of FIG. 2.
The force characteristics of each of these strokes are
described hereinafter with reference to FIG. 4 which
5 illustrates these force characteristics.

Thus, the non-magnetic section 37 of the tube
provides a gap which is reduced in magnetic force, shown
in FIG. 2 between the lines B to D (hereinafter referred
to as reduced magnetic gap) illustrated so that in the
10 present embodiment the reduced magnetic gap is coaxially
the same as the air gap 38, thereby also extending between
the lines B and D of FIG. 2; thus is provided a reduced
magnetic gap coaxially longer than the full stroke of the
armature which extends only between the lines B and E of
15 FIG. 2. It will be understood by one skilled in the art
that the coaxial distance of the non-magnetic section 37
can be selectively varied in order to permit the desired
selected magnetic forces to be produced on the armature 45
in order to get the resulting desired selected propor-
20 tional forces output and forces curve. One such desired
curve is shown in FIG. 4; other curves can be obtained as
desired. As already described, the armature tube 36 may
be constructed of completely non-magnetic material such as
non-magnetic stainless steel. What is important is that
25 the non-magnetic section 37 of the armature tube 36
extends coaxially at least a selected portion of the
armature stroke sufficient to permit selected magnetic
forces to be produced on the armature 45 to get the
desired selected proportional forces output and curve.

30 An external cylindrical surface 46 of the
armature 45 is provided with a pair of cylindrical spaced
uniform non-magnetic bearing surfaces 64 made by electro-
less nickel plating. Thus, a uniform non-magnetic space
is provided between the armature 45 and the armature tube
35 36, which minimizes the effects of frictional and side-
loading forces. A non-magnetic brass shim 66 is provided
to eliminate the portion of the stroke which yields
undesirable rising force characteristics as illustrated by
that portion of the curve on the FIG. 4 graph between the

The graph illustrated in FIG. 4 shows a typical force vs. stroke curve for the FIG. 2 solenoid which has a 20ohm coil with a size of 1.75 inch outside diameter, 2 inches long, and an .88 inch diameter bore. The forces shown by the solid line 74 between the lines E and C (FIG. 4) are termed "overtravel" stroke and are used when additional stroke gap is required beyond the "working" stroke gap C-B. The additional stroke gap may be required for some other use, for example on a double-solenoid hydraulic valve. The force shown by solid line 72 between the lines C and B of FIG. 4 shows a substantially constant force characteristic which illustrates the force during the solenoid "working" stroke as the armature 45 moves from the partially energized "C" position of FIG. 2 toward the fully energized (solid line) "B" position of FIG. 2. The broken line force, shown by the curve or line 70 between lines B and A (FIG. 4) is generally undesirable and is eliminated as described above by inserting the shim 66.

FIG. 3 illustrates a portion of a second embodiment of this invention in which the relative positions of the radially externally facing frusto-conical surface 54 (FIG. 2) and recess 56 (FIG. 2) of the stationary pole piece 39 are reversed. Thus, a radially externally facing frusto-conical surface 76 is provided on armature 78 of FIG. 3 and likewise there is a corresponding reversal of the parts by incorporating a reduced in cross section cylindrical end portion or nose 84 corresponding to the nose piece 62 of FIG. 2 on a stationary pole piece 82 of FIG. 3. The radially externally facing frusto-conical surface 76 surrounds an axial cylindrical concentric recess 80 corresponding to the recess 56 of the stationary pole piece 39 in FIG. 2. The armature 78 and the stationary pole piece 82 are maintained in concentricity by an armature tube 86. The rest of the structure of the FIG. 3 embodiment is the same as in the FIG. 2 embodiment.

Fixed and movable pole pieces arranged within an armature tube to have a complementary recess and reduced in cross section end portion disposed within the recess

offer possibilities for frusto-conical pole piece sections
1 other than the externally facing frusto-conical surfaces
surrounding a pole piece recess as explained above
relative to FIGS. 2 and 3. These other frusto-conical
pole piece sections were envisioned as possibilities when
5 my parent application was filed and have now been
confirmed by experimentation to be practical. My
preferred embodiments of these alternatives are shown in
FIGS. 5-8.

All these alternatives share the basic structure
10 explained above relative to FIGS. 2 and 3, including fixed
and movable pole pieces concentrically aligned within
armature tube 36 and preferably using the same solenoid
components and structure as described in more detail
above. These alternatives also share with the embodiments
15 of FIGS. 2 and 3 the basic structure of a recess 56 formed
in the end of one pole piece, and a complementary projec-
tion or nose 62 formed in the other pole piece to be
disposed within the recess 56.

Alternative frusto-conical pole piece sections
20 can then be formed relative to complementary recesses and
end projections as shown in FIG. 5 for a conic section
formed on movable armature 45a and in FIG. 6 for a conic
section formed on fixed pole piece 39b. Instead of having
a conic section with a radially externally facing frusto-
25 conical surface surrounding recess 56a of fixed pole piece
39a of FIG. 5 or recess 56b of movable armature 45b of
FIG. 6, the reduced in cross section end portion or nose
62a or 62b complementary to recess 56a or 56b is formed
with a radially inward facing frusto-conical surface 95
30 disposed within recess 56a or 56b. This arrangement, like
the embodiments shown in FIGS. 2 and 3, can also produce a
proportional solenoid with a force-stroke curve having a
linear portion such as shown in FIG. 4.

Pole pieces 45a, 39a, 45b, and 39b, are other-
35 wise concentrically aligned within armature tube 36 as
previously explained, and the rest of the solenoid
structure preferably uses the same components as described
in more detail relative to the embodiment of FIG. 2.
These include a washer-shaped shim 66a between armature

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1 shoulder 42 and fixed pole piece 39a or 39b to limit the
approach together of the fixed and movable pole pieces for
the same purpose as shim 66 in the embodiment of FIG. 2.
Also included are push rod 60 extending through bore 58 in
5 a fixed pole piece, although this is not used for pull-
type solenoids.

I have discovered further that pairs of opposed
and confronting conic sections between fixed and movable
pole pieces as shown in FIGS. 7 and 8 can also produce a
proportional solenoid. Movable armature 45a of the
10 embodiment of FIG. 7 is similar to the movable armature
45a of the embodiment of FIG. 5, but fixed pole piece 39c
has an externally facing frusto-conical surface 54a
surrounding recess 56a, similar to frusto-conical surface
54 of the embodiment of FIG. 2. The frusto-conic sections
15 that overlap and move relative to one another between
inward facing frusto-conical surface 95 and outward facing
frusto-conical surface 54a can produce a force-stroke
curve with a linear section as shown in FIG. 4.

A stop device must limit the approach of movable
20 armature 45a toward fixed pole piece 39c; and since there
is no room for a conventional shim 66, such as used in the
embodiments of FIGS. 2, 3, 5, and 6, I prefer abutment
pins or a stop collar 96 secured to push pin 60.

The embodiment of FIG. 8 reverses the config-
25 uration of FIG. 7, with recess 56b formed in movable
armature 45c and reduced cross section end piece or nose
62a formed in fixed pole piece 39b. This disposes
radially inwardly facing frusto-conical surface 95 within
recess 56b, which is surrounded by radially outwardly
30 extending frusto-conical surface 54a. The effect is
similar to the solenoid of FIG. 7.

The invention has been described in detail above
with particular reference to preferred embodiments
35 thereof, but it will be understood that variations and
modifications can be effected within the spirit and scope
of the invention as described hereinabove and as defined
in the appended claims.

I claim:

- 1 1. An assembly for use in a solenoid comprising:
 - a. a hollow solenoid armature tube adapted to
be received in a solenoid coil, said tube
having an armature chamber therein;
 - 5 b. a stationary pole piece member fixed in and
defining one end of said armature chamber;
 - c. an armature member positioned in said
armature chamber of said tube for axial
sliding movement relative to and defining
10 an armature stroke relative to said pole
piece member;
 - d. one of said members having an axially
extending recess therein and the other
member having a reduced in cross section
15 end portion adapted to be received in and
complementary to said recess;
 - e. said other member having a radially
internally facing frusto-conical surface
formed on said reduced in cross section end
portion and disposed within said recess;
 - 20 f. said armature tube having a non-magnetic
section defining a reduced magnetic gap
extending coaxially with at least a portion
of said armature stroke sufficient to
25 permit selected magnetic forces to be
produced on said armature; and
 - g. said armature tube providing concentricity
of said two members.
2. An assembly in accordance with claim 1 in which
30 said armature tube comprises a one-piece metal tube.
3. An assembly in accordance with claim 1 including
non-magnetic bearing means between said armature member
and said armature tube for reducing friction.
4. An assembly in accordance with claim 3 in which
35 said bearing means provides a non-magnetic space between
said armature member and said armature tube.
5. An assembly in accordance with claim 4 in which
said bearing means comprises multiple circumferential
bearing surfaces spaced linearly along said armature.

6. An assembly in accordance with claim 1 in which
1 said stationary pole piece member has a reduced in cross
section part adapted to be received in and mate with the
internal surface of one end of said armature tube.

7. An assembly in accordance with claim 1 in which
5 said armature tube comprises a one-piece semi-austenitic
material tube treated to be non-magnetic along said
non-magnetic section of said tube.

8. An assembly in accordance with claim 1 in which
said armature tube comprises a non-magnetic one-piece tube.

10 9. An assembly in accordance with claim 1 in which
said armature tube comprises a non-magnetic metal
one-piece tube.

10. An assembly in accordance with claim 1 wherein
said one member has a radially externally facing
15 frusto-conical surface surrounding said recess and
extending into said chamber.

11. An assembly for use in a solenoid comprising:

- 20 a. a hollow solenoid armature tube adapted to
be received in a solenoid coil, said tube
having an armature chamber therein;
- b. a stationary pole piece member fixed in and
defining one end of said armature chamber;
- c. an armature member positioned in said
25 armature chamber of said tube for axial
sliding movement relative to and defining
an armature stroke relative to said pole
piece member;
- d. one of said members having an axially
30 extending recess therein and the other
member having a reduced in cross section
end portion adapted to be received in and
complementary to said recess;
- e. said other member having a radially
35 internally facing frusto-conical surface
formed on said reduced in cross section end
portion and disposed within said recess;

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- 1 f. said armature tube having a non-magnetic
section means providing a reduced magnetic
gap extending coaxially with at least a
portion of said armature stroke sufficient
to permit selected magnetic forces to be
5 produced on said armature; and
g. said armature tube providing concentricity
of said two members.

12. An assembly in accordance with claim 11 in which
said armature tube comprises a one-piece metal tube.

10 13. An assembly in accordance with claim 11 in which
said stationary pole piece member has a reduced in cross
section part adapted to be received in and mate with the
internal surface of one end of said armature tube.

14. An assembly in accordance with claim 11 in which
15 said armature tube comprises a one-piece semi-austenitic
material tube treated to be non-magnetic along said
non-magnetic section of said tube.

15. An assembly in accordance with claim 11 in which
said armature tube comprises a non-magnetic metal one-
20 piece tube.

16. An assembly in accordance with claim 11 wherein
said one member has a radially externally facing frusto-
conical surface surrounding said recess and extending into
said chamber.

25 17. An assembly for use in a solenoid comprising:

- a. a one-piece cylindrical metal hollow
solenoid armature tube adapted to be
received in a solenoid coil, said tube
having a cylindrical armature chamber
30 therein;
- b. a stationary pole piece member fixed in and
defining one end of said armature chamber;
- c. a cylindrical armature member positioned in
said armature chamber of said tube for
axial sliding movement defining a stroke
gap relative to and defining an armature
35 stroke relative to said pole member;

- 1 d. one of said members having an axial
concentric cylindrical recess therein and
the other cylindrical member having a
reduced in cross section axial cylindrical
concentric end portion adapted to be
5 received in and complementary to said
recess;
- e. said other member having a radially
internally facing frusto-conical surface
formed on said reduced in cross section end
10 portion and disposed within said recess;
- f. said armature tube having a non-magnetic
section means providing a reduced magnetic
gap extending coaxially with at least a
portion of said armature stroke sufficient
15 to permit selected magnetic forces to be
produced on said armature; and
- g. said armature tube providing concentricity
of said two members.

18. An assembly in accordance with claim 17
20 including non-magnetic bearing means between said armature
member and said armature tube for reducing friction.

19. An assembly in accordance with claim 18 in which
said bearing means provides a non-magnetic space between
said armature member and said armature tube.

25 20. An assembly in accordance with claim 19 in which
said bearing means comprises surfaces spaced linearly
along said armature.

21. An assembly in accordance with claim 17 in which
said stationary pole piece member has a reduced in cross
30 section part adapted to be received in and mate with the
internal surface of one end of said armature tube.

22. An assembly in accordance with claim 17 in which
said armature tube comprises a one-piece semi-austenitic
material tube treated to be non-magnetic along said
35 non-magnetic section of said tube.

23. An assembly in accordance with claim 17
including a solenoid coil surrounding said armature tube.

24. An assembly in accordance with claim 17 wherein
1 said one member has a radially externally facing
frusto-conical surface surrounding said recess and
extending into said chamber.

25. A method of providing an assembly for use in a
5 solenoid comprising the steps of:

- a. providing a hollow solenoid armature tube
adapted to be received in a solenoid coil,
said tube having an armature chamber
therein;
- 10 b. providing a stationary pole piece member
fixed in and defining one end of said
armature chamber;
- c. providing an armature member positioned in
said armature chamber of said tube for
15 axial sliding movement relative to and
defining an armature stroke relative to
said pole piece member;
- d. providing one of said members with a recess
therein and the other member with a reduced
20 in cross section end portion adapted to be
received in and complementary to said
recess;
- e. providing said other member with an
internally facing frusto-conical surface
25 formed on said reduced in cross section end
portion and disposed within said recess;
- f. providing said armature tube with a
non-magnetic section defining a reduced
magnetic gap extending coaxially with at
30 least a portion of said armature stroke
sufficient to permit selected magnetic
forces to be produced on said armature; and
- g. said armature tube providing concentricity
of said two members.

35 26. A method in accordance with claim 25 in which
said armature tube is provided as a one-piece metal tube.

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27. A method in accordance with claim 25 including
1 the step of providing a non-magnetic bearing means between
said armature member and said armature tube for reducing
friction.

28. A method in accordance with claim 27 in which
5 said bearing means is provided as a non-magnetic space
between said armature member and said armature tube.

29. A method in accordance with claim 25 in which
said bearing means is provided as multiple circumferential
bearing surfaces spaced linearly along said armature.

10 30. A method in accordance with claim 25 in which
said stationary pole piece member is provided with a
reduced in cross section part adapted to be received in
and mate with the internal surface of one end of said
armature tube.

15 31. A method in accordance with claim 25 in which
said armature tube is provided as a one-piece
semi-austenitic material tube treated to be non-magnetic
along said non-magnetic section of said tube.

32. A method in accordance with claim 25 including
20 providing a solenoid coil surrounding said armature tube.

33. A method in accordance with claim 25 including
providing said one member with an externally facing
frusto-conical surface surrounding said recess and
extending into said chamber.

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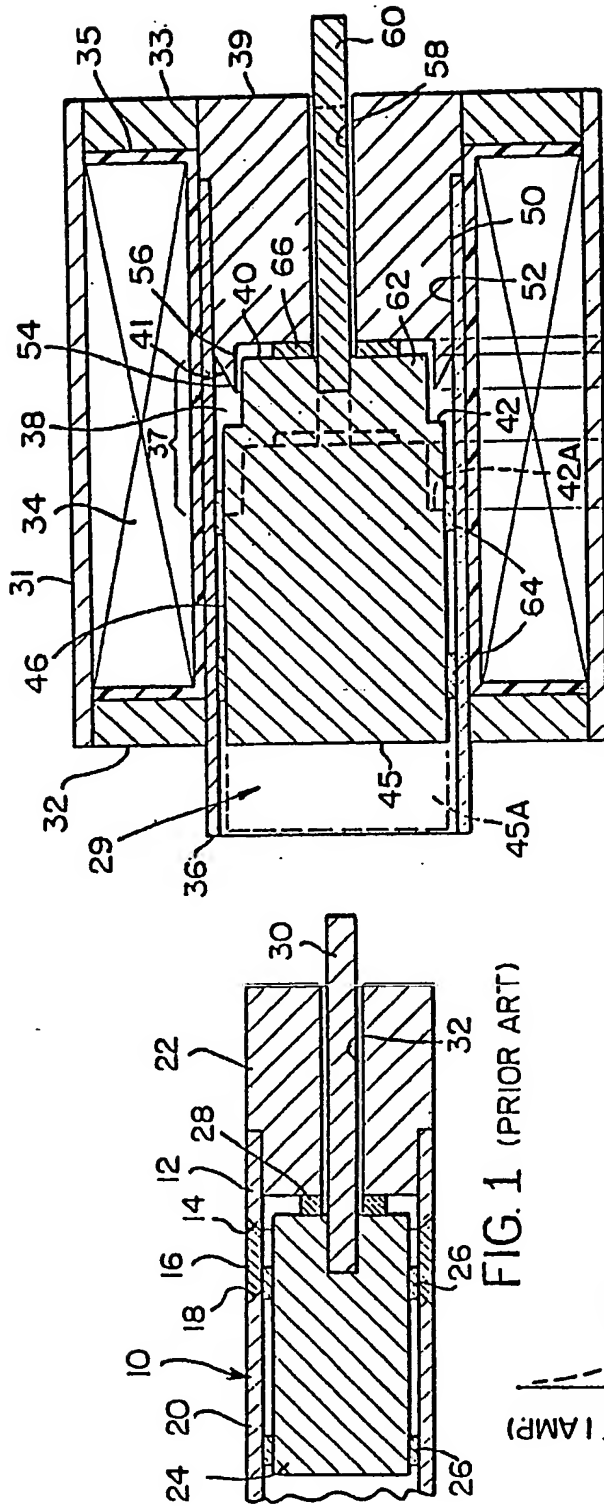


FIG. 1 (PRIOR ART)

FIG. 2

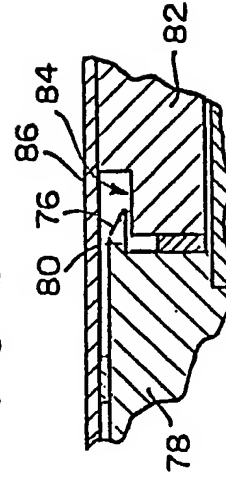


FIG. 3

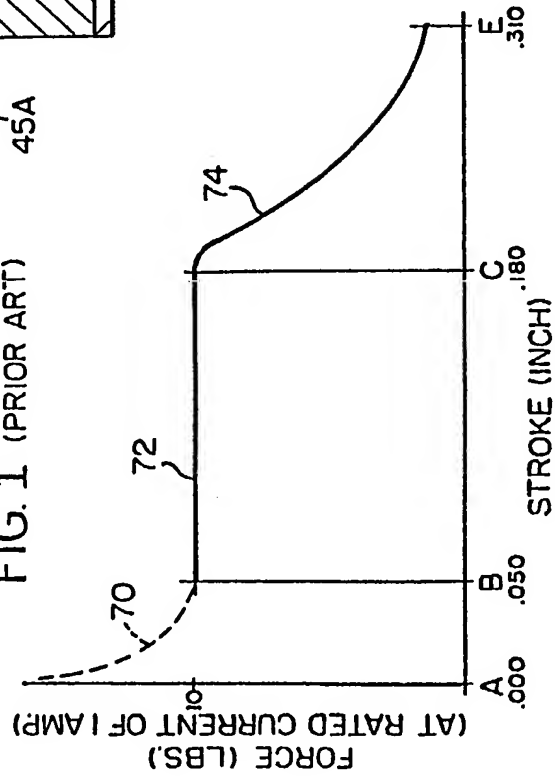


FIG. 4

FIG. 5

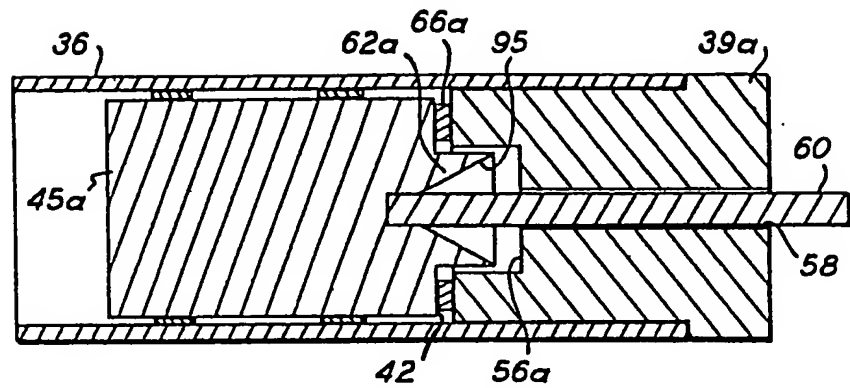


FIG. 6

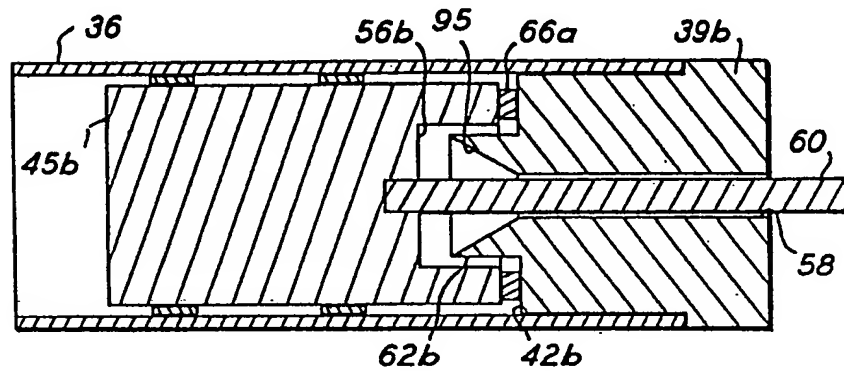


FIG. 7

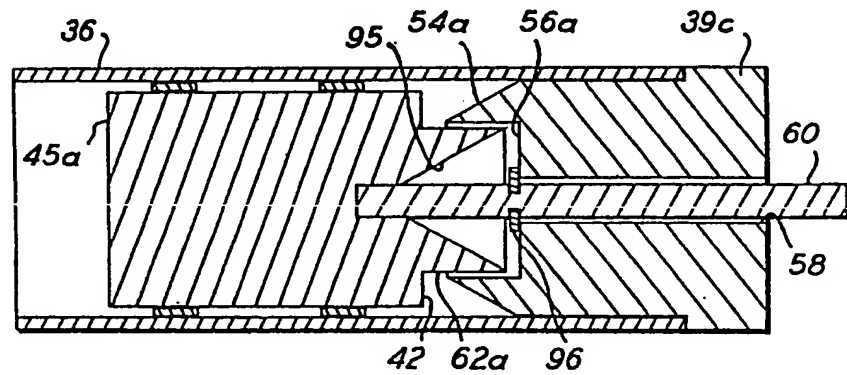
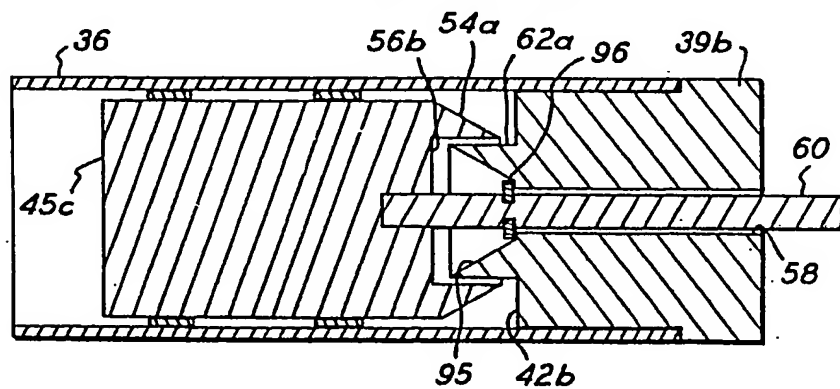


FIG. 8





DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
Y	US-A-4 166 991 (L. HANER) * Column 9, line 45 - column 10, line 56, figure 6; column 3, lines 46-57, figure 1 *	1	H 01 F 7/13 H 01 F 7/16
A		2, 7-9, 12, 14, 15, 22, 23, 26, 31, 32	
Y	DE-A-3 318 034 (KROME) * Page 10, line 9 - page 11, line 12, figure 1; page 11, line 30 - page 12, line 13, figure 2 *	1	
A		10, 11, 16, 17, 24, 25, 33	TECHNICAL FIELDS SEARCHED (Int. Cl. 4) H 01 F 7/00
A	US-A-4 127 835 (KNUTSON) * column 3, lines 39-46, figure 3 *	3-5, 18-20, 27-29	
P, A	EP-A-0 146 951 (LISK) * Whole document *	1-33	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12-09-1986	Examiner BIJN E.A.
CATEGORY OF CITED DOCUMENTS			
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Category	Citation of document with indication where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	EP-A-0 024 909 (LEDEX)		
A	DE-C- 847 465 (BINDER) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12-09-1986	Examiner BIJN E.A.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	